Terror-Related Injuries: A Comparison of Gunshot Wounds Versus Secondary-Fragments—Induced Injuries from Explosives

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BACKGROUND: Terror-related injuries caused by secondary fragments (SF) from explosive devices show a distinctive pattern in severity, distribution, outcomes of assault, and health-system resource use as compared with terror-related penetrating injuries caused by gunshot wounds.

STUDY DESIGN: A case-comparison study conducted in a tertiary university hospital and the only Level I trauma center in the Jerusalem vicinity. During a period of 4 years, over 1,500 casualties of terror-related injuries were treated in one Level I trauma center. The study included 533 patients who were admitted for hospitalization. Excluded from the study were victims who were dead on arrival or who succumbed to their injuries within 30 minutes of arrival at the emergency department. Data were collected from trauma registry records.

RESULTS: Gunshot-wound victims were mostly men, aged 19 to 30, and SF victims were more evenly distributed between the genders and across the age spectrum. Injury Severity Score (ISS) was considerably higher in SF victims, although critical mortality rates were higher in gunshot-wound victims. More than 40% of SF victims were injured in three or more body regions, as opposed to < 10% in gunshot-wound victims. Use of imaging modalities and ICUs was considerably higher for SF victims.

CONCLUSIONS: Terror victims suffering from SF wounds have more complex, widespread, and severe injuries than victims suffering from gunshot wounds. They tend to involve multiple body regions and use more in-hospital resources. Attenuation of bus seats and protective vests can lead to a reduction in severity of these injuries. (J Am Coll Surg 2006;203:297–303. © 2006 by the American College of Surgeons)

Terror is becoming an increasing concern for trauma care providers and health administrators, with the threat increasing tremendously over the last several years. Terror-related injuries, especially those seen with suicide-bomber attacks, are associated with a unique pattern of injury that must be dealt with explicitly to decrease the associated morbidity and mortality.[1-3] Most terror victims are injured either by explosive devices set in civilian or military scenarios, usually in the course of mass casualty incident or from gunshots, and in military or secluded settings.

Mechanisms of injury associated with explosions are traditionally divided into primary, secondary, and tertiary blast injuries. Primary blast injury occurs as a result of the blast wave-mediated atmospheric pressure change.[4-6] Secondary damage is caused by missiles and fragments, either embedded inside the explosive device (eg, bolts, ball bearings, nails) or its casing, or from the shattering effect of the blast on its surroundings (eg, glass). These secondary missiles are propelled by the blast energy, hitting the patient. Tertiary damage is caused by displacement of the patient's body by the blast wind powerful energy and consequent impact with the ground or surrounding structures. Additional damage, sometimes referred to as "quaternary blast injury," is caused by flash burns from the hot gases and extreme heat caused by the explosion itself. Burns typically affect exposed body parts, such as face, neck, and upper ex-

Competing Interests Declared: None.

Received February 4, 2006; Revised March 29, 2006; Accepted May 9, 2006.
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Published by Elsevier Inc.

ISSN 1072-7515/06/$32.00
doi:10.1016/j.jamcollsurg.2006.05.010

Abbreviations and Acronyms

AIS = Abbreviated Injury Scale
ISS = Injury Severity Score
SF = secondary fragments

tremities, and cause damage from ignition of flammable material, such as clothing.[5] Crush injuries[7] from collapsing structures can lead to traumatic rhabdomyolysis followed by acute renal failure, one of the most prominent and fearful complications of crush syndrome.[8] Other forms of quaternary damage are associated with inhalation of toxic agents. Secondary missiles—fragments injuries caused by metal debris embedded especially within suicide bomber's belts—are associated with unique injuries. Comparison of injuries associated with gunshot wounds with those caused by secondary fragments (SF) can be relevant to trauma care providers managing injuries of terror victims as well as to those involved with the designing of personal protection devices.[9] During the last 5 years of an extensive terror wave in Israel, 7,520 Israelis were injured by terrorist activity, with 1,074 killed.[10] Thirty-four percent of these casualties (n = 2,547) were treated at the Hadassah Ein-Kerem University Hospital in Jerusalem. Using this extensive experience of terror-related injuries, we try to define the unique patterns and characteristics of injury caused by secondary missiles from explosive devices as opposed to gunshots.

METHODS

Data of all patients admitted to the Hadassah Ein-Kerem University Hospital in Jerusalem for terror-related injuries between September 29, 2000 (first day of current wave of terror) and December 31, 2004 were reviewed. Included in the study were victims who suffered from injuries inflicted by an explosive device or gunshot wounds. (E codes 991 for bullets-induced injury and 993 for explosive-device victims). Excluded were victims who were dead on arrival or those who succumbed to their injuries within 30 minutes of arrival at the emergency department. Data were collected from the hospital's trauma registry and included vital signs on arrival at the emergency department, procedures conducted in the emergency department and in operating theaters, and interventions undertaken in the different wards. Different trauma scores were generated using the trauma registry software, including Abbreviated Injury Scale (AIS),[11] Injury Severity Score (ISS),[12] and Revised Trauma Score.[13]

Statistical analysis was performed using the SPSS 11.0 software (SPSS Inc). Mann-Whitney nonparametric test and *t*-test were used for quantitative variables; Pearson's chi-square test was used with categorical data. A p value < 0.05 was considered statistically significant.

RESULTS

From a total of 1,552 victims treated during the study period, 533 met the study criteria. Of these, 208 suffered SF injuries and 325 gunshot wounds. Almost 90% of gunshot victims were men and 60% were aged 19 to 30 years (Table 1). Age and gender were more equally distributed in the SF group. Mean age of gunshot victims was 27.4 ($\pm$12.9 SD) years, and that of SF victims was 28 ($\pm$14.6 SD) years. Soldiers represented 34.4% (n = 112) of those injured by gunshots, as compared with only 19.7% (n = 41) of those injured by SF.

Injury severity and distribution

Median ISS and rate of severe (ISS $\geq$ 16) or critical injuries (ISS $\geq$ 25) were greater for SF injuries than for gunshot wounds ($p < 0.001$ and $p = 0.013$, respectively, Fig. 1). Of SF victims, 45.2% suffered from severe and critical injury (ISS $\geq$ 16) in comparison with only 31.3% of gunshot victims ($p < 0.001$). Revised Trauma Score and Glasgow Coma Scale (GCS) were similar for gunshot wounds and SF victims (Table 2). Maximal AIS mean was similar in both groups, although the rate of victims sustaining more extensive injuries (maximal AIS $\geq$ 4) was greater for SF than for gunshot victims (Table 3). SF victims were more likely to be injured in multiple

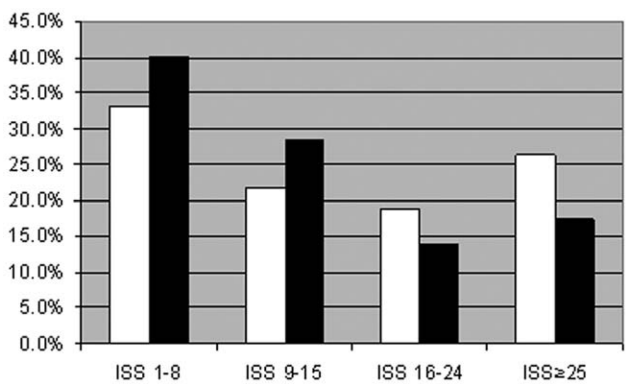

Figure 1. Injury Severity Score (ISS) distribution. Secondary fragments, white bar; gunshot wound, black bar.

Table 1. Demographic Data

	Secondary fragments		Gunshot wound		
	n	%	n	%	p Value
Age (y)					
0–18	57	27.4	37	11.4	< 0.001
19–30	82	39.4	196	60.3	< 0.001
31–50	48	23.1	72	22.2	NS
> 50	21	10.1	20	6.2	NS
Gender					
Male	111	53.4	289	88.9	< 0.001
Female	97	46.6	36	11.1	< 0.001

body regions, according to the AIS classification (Table 4). Over 40% of SF victims were injured in three or more distinct body regions, as compared with 9.6% among gunshot victims. Gunshot victims were almost exclusively injured in one or two separate regions.

There was a marked notable difference in injury distribution. Although most gunshot victims were injured in the trunk, abdomen, and extremities, SF victims were much more likely to sustain injuries to upper body regions as well (Fig. 2, Table 5). In-hospital mortality from gunshots was greater than from SF, although absolute figures were very low for both (27 and 12, respectively). Crude mortality, relating to all casualties and including victims with mild injuries, was not significantly different between the groups. Mortality rates for severe and critically injured (ISS $\geq$ 16) victims were considerably higher for gunshot victims (Table 4).

Hospital resources use

There was no notable difference between the average length of stay of patients in either group (Table 6). Of SF victims, 48.6% required treatment in the ICU as compared with only 35.6% of gunshot victims ($p = 0.003$). No notable difference was observed between the groups about the length of ICU stay.

Imaging resource use during the initial evaluation (while in the emergency department) was markedly different for CT scan and ultrasonography (Table 6). Of SF victims, 48.1%, and 38.7% of gunshot victims, underwent CT scan ($p = 0.032$). Fifty percent and 25.8%, respectively, underwent a focused abdominal ultrasonography in trauma in the emergency department ($p < 0.001$).

There was no statistically significant difference between the need for surgical intervention about total number of episodes in the operating room between the two groups.

DISCUSSION

The vast majority of those inflicted with injuries from gunshots were young (60% aged 19 to 30 years) and were men (90%). This is explained by the fact that members of the main group injured by this mechanism were soldiers (34.4%), drivers, or hikers in isolated regions. In contrast, SF injuries were divided almost equally between genders, reflecting the civilian settings (buses, shopping malls, discotheques, and so forth) that serve as terrorist targets. Interestingly enough, the mean age for SF injuries is also relatively young (27.4 years), because of the presence of victims from both extremes of the age curve (young children and elderly persons alike).

We show that injuries from explosive devices containing secondary missiles are usually more severe with respect to median ISS and rate of severe or critical injury (ISS $\geq$ 16). This finding can be explained by the multiple mechanisms of injury conveyed by an explosive device and by the continuous improvement in quality and

Table 2. Abbreviated Injury Scale Scores

	Secondary fragments		Gunshot wound		
	Mean	SD	Mean	SD	p Value
Glasgow Coma Scale	13.14	3.9	13.2	3.8	NS
Revised Trauma Score	7.19	1.5	7.06	1.8	NS
Injury Severity Score (median)	13	14	9	10.1	< 0.001
Maximal Abbreviated Injury Scale (mean)	2.98	1.3	2.84	1.1	NS

Table 3. Trauma Scores (Continued)

	Secondary fragments		Gunshot wound		
	n	%	n	%	p Value
Max AIS					
1	31	14.9	35	10.7	NS
2	44	21.2	98	30.1	0.023
3	63	30.3	116	35.6	NS
4	40	19.2	38	11.7	0.016
5	29	13.9	38	11.7	NS
6	1	0.5	1	0.3	NS
AIS ≥ 4	70	33.7	77	23.6	0.011

AIS, Abbreviated Injury Scale.

design of these explosive devices as related to the explosive material and the embedded fragments. The physiologic scores indicated considerable similarities between the SF and gunshot groups. It has been shown[14] that most victims of terrorist bombings (853 of 906) arrived at hospital hemodynamically stable (systolic blood pressure > 90 mmHg) and that even among those later shown to be severely injured (ISS ≥ 25) only 21.5% (34 of a total of 160) arrived at the emergency department hemodynamically compromised. In both, the previously mentioned and current study, time for evacuation to the hospital is usually short, as is the case for most terrorist attacks in Israel.[15] Under such conditions, physiologic injury scores are unreliable criteria for comparison between groups of injured. Our data shows a distinctive pattern of injury in SF with respect to the affected body region. Victims injured by SF, as expected, were more likely to suffer from injury to numerous body regions (three or more, 40.9% in SF; as compared with only 9.6% for gunshot wounds). The main reason for this difference is the abundance of multiple secondary missiles embedded in the explosive devices. It is not surprising that the distribution of injuries is related to body surface area of the different regions. The face, which represents < 4% of total body surface area, was more frequently injured by SF than by gunshots (49.5% versus 14.7%, respectively). One possible explanation for this finding is the greater vulnerability and exposure of the face compared with other parts of the body, which are partially protected against small-sized fragments by clothing, shopping bags, and car seats, among other items. This protection is much more pronounced in military and paramilitary setups. Another feasible explanation for this finding is that minimal injuries that can be neglected in some body region, such as a scratch on the arm from small fragments, is more noticeable when affecting the delicate superficial structures of the face.

Peleg and colleagues[16] failed to show a statistically significant difference in crude mortality between explosive device victims and gunshot victims. Our data show that critical mortality for patients arriving alive at the emergency department, which is a more accurate measure of outcomes of medical management of mass casualties[17,18] is considerably higher for gunshot wounds than for SF injuries. This finding can be explained by the fact that critically injured victims in the gunshot-wound group are often injured by a single severe injury to which they succumb, and victims of SF are often injured by several injuries of lesser magnitude. Another factor that can affect mortality is longer evacuation time for soldiers

Table 4. Injury Distribution* and Mortality

	Secondary fragments		Gunshot wound		
	n	%	n	%	p Value
1 body region	57	27.4	190	58.3	< 0.001
2 body regions	65	31.3	102	31.3	NS
3 body regions	46	22.1	23	7.1	< 0.001
≥ 4 body regions	39	18.8	8	2.5	< 0.001
Overall mortality	12	5.8	27	8.3	NS
Critical mortality†	12	12.8	27	26.5	0.016

*According to Abbreviated Injury Scale six body regions: head and neck, face, skin, abdomen and pelvis, thorax, extremities.
†Critical mortality: mortality based only on those critically injured (Injury Severity Score ≥ 16).

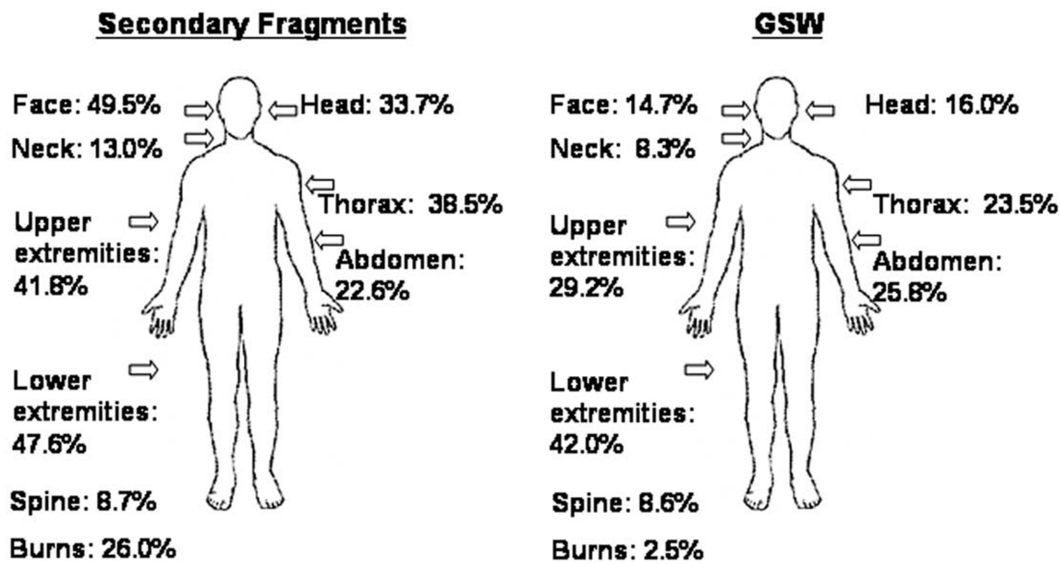

Figure 2. Injury distribution. GSW, gunshot wound.

wounded on the battlefield, given the substantial portion of soldiers among gunshot victims as indicated earlier. SF injuries, on the other hand, are typically associated with mass casualty incidents that usually takes place in an urban setting. Yet another reason for higher mortality rate of gunshot victims is that, unlike SF injuries, which are usually acquired in the setting of a mass casualty incident, when the entire hospital system is at maximum readiness to receive and provide immediate care for large numbers of casualties,[19] gunshot wounds are usually isolated cases, are often incurred at night time, with initial care usually delivered by available on-call staff, primarily residents and junior physicians. The Hadassah hospital trauma registry includes data about in-hospital mortality and morbidity. In an attempt to define the denominator, which includes prehospital mortality rates as well, we refer to data on the relevant populations and time period in terror registries of non-medical academic research institutes. According to these registries 1,357 Israelis were injured and 175 died as a result of suicide and nonsuicide terror-related explosions in Jerusalem[20] (crude mortality rate of 11.4%). Five-hundred fifty-five people were injured and 277 were killed from terror-related gunshot incidents during the period of the current study[21] (crude mortality rate of 33.3%). Data published by these research centers, although not making a distinction between fatally or lightly injured victims, correlates with our conclusion of higher in-hospital critical mortality rates for gunshot wounds over SF injuries.

Use of screening imaging modalities, such as CT scans and focused abdominal ultrasonography in trauma was considerably greater in SF injuries, reflecting a much less defined and localized type of injury and the need to

Table 5. Injury Distribution

	Secondary fragments		Gunshot wound		
Body region	**n**	**%**	**n**	**%**	**p Value**
Burns	54	26.0	8	2.5	< 0.005
Head	70	33.7	52	16.0	< 0.005
Face	103	49.5	48	14.7	< 0.005
Neck	27	13.0	27	8.3	NS
Thorax	80	38.5	76	23.5	< 0.005
Abdomen	47	22.6	84	25.8	NS
Upper extremities	87	41.8	95	29.2	0.003
Lower extremities	99	47.6	137	42.0	NS
Spine	18	8.7	28	8.6	NS

Table 6. Use of Hospital Resources

	Secondary fragments	Gunshot wound	p Value
Mean length of stay ± SD (d)	14.3 ± 16.6	12.42 ± 24.2	NS
Mean ICU length of stay ± SD (d)	4.3 ± 10.3	2.91 ± 8.7	NS
Need for ICU stay, n (%)	101 (48.6)	116 (35.6)	0.003
Emergency department CT, n (%)	100 (48.1)	126 (38.7)	0.032
Emergency department angiography (performed during initial workup), n (%)	13 (6.3)	32 (9.8)	NS
FAST in emergency department, n (%)	104 (50)	84 (25.8)	< 0.001

FAST, focused abdominal ultrasonography in trauma.

search for internal injuries that are not always clearly identified on physical examination. Experience has taught us that the strength of impact and the tract taken by SF within the patient's body are unpredictable. Unlike an injury caused by gunshot, where entrance and exit wounds tend to be visible, SF injuries generally entail many small entrance wounds that make it very difficult to estimate the extent of injury using physical examination exclusively. For this reason, use of CT scans for accurate and rapid diagnosis of penetrating injuries has been added to the protocol for dealing with SF injuries in our institution. Another reason for the difference in use of imaging modalities is that patients with gunshot wounds are often transferred directly to the operating room for immediate operation, without earlier use of ultrasonography to evaluate the presence of free fluid in the peritoneal space (eg, focused abdominal ultrasonography in trauma). Although the average length of stay and the need for operating-room intervention are not substantially different between the two groups, ICU hospitalization rate was much greater for SF injuries, reflecting the multiple patterns of injury, coupled with pronounced hemodynamic instability and vital signs failure.

It is important to note that because of field triage and later interhospital triage,[22] Hadassah Ein-Kerem, which is a Level I trauma center, receives a larger percentage of severely injured victims belonging to both groups of injuries studied, a fact that can be a confounding factor in the current study.

Terror-related injuries are becoming frequently encountered events in Israel and in other parts of the world. Mechanism of injury plays an important role in the behavior of these penetrating injuries and a different pattern of threat is associated with recent terror, which use secondary missiles to a greater extent. These injuries tend to involve more body regions, use more hospital resources, and have better outcomes with regard to critical mortality. It is evident that not only are more body regions affected when dealing with victims of explosive devices, but also distribution of injury is substantially different. More SF victims suffer from facial and head and neck injuries and are exposed to severe damage from small-sized fragments to the vulnerable superficial major vessels in the neck region and the aerodigestive system in the face. Our data demonstrate that in several aspects, ballistics, injury distribution, and magnitude of injury are considerably different for SF injuries and gunshot wounds. These results encourage new approaches for secondary prevention. For example, simple redesigning of bus seats, which would involve an elevated back seat, might provide an anterior and posterior passive barrier from explosion-derived fragments. This measure might improve protection of neck and head area and reduce these superficial but often severe injuries. Modern military personal armor systems routinely in use today by Western armies, such as the KEVLAR vests (DuPont) and Personal Armor System Ground Troops helmets provide only partial protection, and leave the areas of the face and neck highly vulnerable. Forensic analysis of recent military casualties[9,23] showed a propensity, similar to the one shown in the current study, toward face and neck injuries in both bullet and fragment groups. For soldiers, the balance between protection and mobility should be weighted, although for secondary terror injury prevention under civilian context, emphasis should be targeted toward environmental measures. Ongoing processing of injury patterns is crucial for better design of protective measures against fragment and bullet injuries alike.

Author Contributions

Study conception and design: Sheffy, Rivkind, Shapira
Acquisition of data: Sheffy

Analysis and interpretation of data: Sheffy, Mintz, Shapira
Drafting of manuscript: Sheffy, Mintz, Shapira
Critical revision: Mintz, Rivkind, Shapira

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